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This report covers visits to several of Turkey's leading technical institutions and provides a survey of some of their facilities and ongoing research in applied material science; primarily with minerals, ceramics, polymers, and elastic constants. The institutes visited included: Middle East Technical University (METU), Ankara; Turkish Scientific and Technical Development Agency (Tübitak), Ankara; Mining Research Institute Ankara (MTA); Tübitak Electronics and Electrical Research Institute, Ankara; Marmara Research Institute, Gebse; and Ankara Nuclear Research and Training Center (ANAEM).

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APPLIED MATERIAL SCIENCE IN TURKEY

1 INTRODUCTION

The opportunity to return to Turkey to visit universities and research institutes came as a great pleasure to me since I had taught in the Physics Department of the Middle East Technical University (METU) in Ankara during 1969 and 1970 and had kept in touch with several faculty members over the years. The arrangements for my visits were helped by two professors from the Physics Department, Dr. H. Özkan and Dr. Ay Melek Ozer; with their help I was able to overcome my lack of knowledge of where work is in progress in Turkey in the field of material science and related subjects. They helped me prepare a preliminary set of visits and contacts in the Physics Departments of the five universities in Ankara, (METU, Gazi, Hacetteppe, Ankara, and Bilkent Universities). I was able to expand this to include several research organizations.

The Physics Department of METU occupies a rather important role in the development of science in Turkey in recent years, with many past members of the department now being chairmen and directors of other university departments, research organizations, and also being in the political field. The faculty of the Physics Department greeted me with great warmth and even allocated an office for my use. I gave a colloquium on "Heavy Ion Bombardment of Crystal Structures" in METU and also in Gazi University. Though invited to give talks in the other universities in Ankara, I was not able to undertake these due to lack of time.

There is no special department of material science or ceramics in METU. Therefore, I visited the departments where such work is going on. The research institutes I was able to see were the Atomic Energy Laboratory (ANAEM) at Ankara; the Mining Research Institute (MTA); the Electrical and Electronics Research Institute attached to the Electrical Engineering Department of METU; and the Marmara Research Institute, in Gebse, near Istanbul.

I visited the offices of Tübitak in Ankara; Tubitak is the organization of Turkish Scientific and Technical Development which is responsible for all research grants to Turkish Universities, operates five research institutes in Turkey, provides funds for attendances at conferences, and promotes cooperation between the universities, research institutes and industry. I now realize that, with such functions, this is the most important organization to contact for information about scientific activities in Turkey. Dr. Mehmet Tomak is one of the three advisors responsible to the Director of Tübitak. Previously Dr. Tomak was chairman of the Department of Physics, METU, and in 1980 moved to his present appointment while retaining his research activities at METU. His subject is solid-state physics and he is probably one of the most knowledgeable scientists in this field in Turkey. With his help I was able to visit the various research institutes and especially the Marmara Research Institute in Gebse. I was not able to visit the other research institutes of Tübitak such as the Building Materials Institute, which is in the process of moving onto the METU campus. Furthermore, my visit to the Marmara Research at Gebse, near Istanbul was condensed into one day, much too short to visit an institute of that size. I did not realize the extent of the Marmara Research Institute which, at first glance, is comparable in size to say the National Bureau of Standards in Washington. The Turkish scientists, who are working under many handicaps, tended to describe their successes in aiding the Turkish industrial development, concentrating their laboratory and equipment developments and their research projects on matters relative to the developing industries in Turkey.

2 ORTA DOGU TEKNIK UNIVERSITESI--MIDDLE EAST TECHNICAL UNIVERSITY (METU)

The Physics Department

The present Department of Physics at METU has resulted from the combination of two earlier departments--experimental physics and theoretical physics. This

fact still has an overall influence on the department, which tends to have more theoretical than experimental studies.

One of the studies being undertaken in experimental physics is the measurement of elastic constants of crystalline materials. H. Özkan has set up a laboratory for the measurement of elastic constants using the ultrasonic pulse echo overlap system (Özkan, 1987). The laboratory has systems available for crystal orientation by Laue back reflection; some of these systems are large industrial devices though others have been made at the university and are suitable for small crystal orientation. There are also crystal slicing devices available. The crystals that have been measured have been of the boron-containing compounds such as damborite, $CaB_2Si_2O_8$, and tourmaline, and also some crystals of ceramic materials such as cordierite. Thermal expansion studies are also underway on these same materials using high-temperature x-ray diffraction techniques.

The work on the boron-containing crystals is intended to be an approach to determine the radiation damage effect on the elastic constants of crystals. Under neutron bombardment boron undergoes a nuclear reaction resulting in the formation of a ^7Li and an alpha particle. The recoil of the lithium and the energy in the alpha particle both result in damage to the crystal structure. This is an extension of earlier studies on zircon--$ZrSiO_4$, which occurs in nature in the metamict form. The present studies have been carried out using the neutron radiation facilities at the atomic energy center in Istanbul.

The METU laboratory facility for elastic constant measurements is well developed but has difficulty in obtaining suitable single crystals sufficiently perfect for ultrasonic pulse echo measurements.

Another Physics Department laboratory is that of A. Melek Özer for archeological dating using electron spin resonance (Özer, 1986). A. Uzun is engaged in a theoretical physics study of scientometrics (Uzun 1986).

The Chemistry Department

At least twelve of the faculty in the Chemistry Department have combined to carry out studies on a common subject--polymer sciences. This is a rather fortunate way to proceed, and with the aid of many people working in the same direction they have been able to make reasonable progress with the modest equipment. They have 12 doctoral students and 16 M.S. students, and during the past 2 years have published more than 50 papers. Many of the scientists have been trained in England, Germany, or the US--a fact clearly indicated by the publications, which are very often written in collaboration with colleagues at universities in those countries.

Levent Toppare has been carrying out electrochemical studies of polymerization of materials such as electroinitiated cationic polymerization of indene and styrene and in general electrocationic copolmerization by direct electron transfer. He has been studying the polymerization of halogenated phenols and also of their metal complexes. He has measured peak potentials by cyclic voltametry and carried out polymerization by constant potential electrolysis. He has noted that polymer film coatings are formed on the electrode's surface as well as polymerization occurring in solution. He reports that the polymer of halogenated phenols form film coatings on the electrodes that are very resistant to heat and flame. This study is continuing and there does seem to be the possibility of forming a high-temperature stable polymer coating (Toppare et al. 1984, 1985 a,b; TÜrker et al., 1984; Akbulut et al., 1984, 1985, 1986a,b,c).

G. Akovali is studying plasma-initiated polymerization; (Akovali and Orhan 1984). The plasma-initiated polymerization has been undertaken of acrylamide and also of hexamethyldisiloxane. Another member of the polymer group, M. Kizilyalli, carries out x-ray diffraction studies of the polymeric materials.

Finally, I would like to mention the work of Leyla Aras who has been undertaking studies of the dielectric

relaxation processes in linear, cross-linked and branched polymers as well as ionomers (Aras and Baysal, 1984; Aras et al., 1984).

The Geological Engineering Department

The chairman of this department, Professor Norman, runs a very well-developed organization, and it was he who made arrangements for me to visit the Mineralogical Institute (MTA). He also introduced me to the mineralogist of his department, C. Unan, who took me to see their seismic center for earthquakes. This is one of 17 such establishments around the world and is funded through the International Geological Data Bank (Unan, 1983). The center has extensive chemical analysis facilities including atomic absorption, x-ray fluorescence, and infrared spectroscopy. They are in constant contact with the International Earthquake Center, Denver, Colorado. This METU laboratory is probably as active as any other seismic center around the world.

The Metallurgical Engineering Department

The Metallurgical Engineering Department has several laboratories. The x-ray laboratory is well equipped to carry out measurements of pole figures and metal texture studies and these are being developed to be computer controlled. There is an electron microprobe analyser, scanning electron microscope, transmission electron microscopes, Mössbauer spectroscopy laboratory, and optical spectroscopy laboratory, as well as the usual metallurgy laboratories. The department chairman, Alpay Ankara, was not available the day of my visit but I was shown his work on composite materials of resin-bonded aircraft parts in which, in collaboration with West Germany's Messerschmitt-Bölkow Blohm, he is studying the simulation of moisture absorption effects, though no further details were available. Some of the faculty of the department had studied at the University of London, some in Germany at the Teknische Hochschule, Darmstadt, others at Stanford University, California, University of Sheffield, England, the University of Missouri at Rolla, while other members of staff obtained their Ph.D.'s in Norway, at Massachusetts Institute of Technology, Cambridge, and at McMaster University, Canada; thus this faculty has good and diverse background.

Tayfur Özturk has been carrying out studies of the texture of metals, with particular interest in magnetic steels and copper bullion alloys (Özturk, 1983; Özturk and Davies, 1984). M. Doruk has specialized in the application of fracture mechanics to stress corrosion cracking and corrosion fatigue (Sarioglu and Doruk, 1984a,b). They have fairly extensive laboratory facilities for this type of study. Their recent work has been on the fracture mechanics characterization of stress corrosion of 7050 aluminum alloys, and they are in the process of studying aluminum lithium alloys. They have a very simple and ingenious system of spraying sodium chloride solution onto high-strength aluminum alloys. This work is supported by AGART of NATO. F. Sarioglu has applied the fracture mechanics parameter C-integral in low carbon steels to attempt to explain stress corrosion in steels.

Other studies in the Metallurgical Engineering Department are on adhesion of thin metallic films on metallic and polymeric substrates (Özenbaş and Tan, 1986) and the crystallization of amorphous silicon thin films, (Özenbaş and Kalebozan 1986).

Of final interest is the metallurgical engineering society, Metalurgi Mühendisleri Odas, Konur Sokak 4/1, Ankara, which organizes conferences in metallurgy and the president is Ms. Necla Yikilmaz.

The Ankara Electrical Research and Development Institute

Although I did not have a chance to visit the electrical engineering department itself I was able to spend some time at the closely related and immediately adjacent Ankara Electrical Research and Development Institute, which is run by Tübitak. The nature and quality of the institute's work reflects in large measure on the quality of the faculty and the

nature of their work. The director is Ayhan Türeli. This institute, established in May 1985, gives an opportunity for the electrical engineering faculty to act both as members of the department and also to use the facilities of this research institute. This institute employs about 40 persons, of whom 25 are trained engineers, and seven are technicians.

There are a surprising number of sponsored projects for such a new organization and some of them I will describe. They are constructing a microwave analog system for data handling purposes for Teletas, which is a telephone communication equipment factory in Istanbul which works with the government post office. They have designed and produced an educational microcomputer which may be compared to the IBM XT. It will be used in secondary schools. They are also involved in a project with European Silicon Structures, Paris, designing very large scale integrated circuitry (VLSI) systems. Another project involves the construction of a tachograph for the Turkish transport industry to be installed in all of the trucks and buses as from end of 1987. They are producing a process control system for the steel industry at Iskenderum. Other projects involve prototypes of current converters and rectifiers for the power supply industry, and supplies and controls for induction furnaces. For the Turkish electricity authority, they are constructing a transient analyzer (400 kilovolt system). This is being done in collaboration with Bonneville Power Administration (BPA), Oregon, USA, as a member of the electrical transient amplifier users' club.

3 ANAEM--THE ANKARA NUCLEAR RESEARCH AND TRAINING CENTER

The director of the Ankara ANAEM is Dr. Ugur Büget. This research institute, financed directly from the Prime Minister's office, employs about 11 Ph.D.'s, of whom six are in physics, three in chemistry, one in electronics, and one in health physics. There are also 20 engineers with Master's Degrees, nine with Bachelor's Degrees and some 16 technicians. At the moment the institute is housed on a site at the back of Ankara University but will soon be moved to new buildings about 35 kilometers outside Ankara. The work that they are undertaking is not directly related to atomic energy research. The projects, in general, cover chemical analysis, reaction physics, electronics, and a health physics service. For chemical analysis they have x-ray fluorescence and neutron activation analysis. Here they provide a service for Turkish industry, carrying out analyses on metals, specimens, and samples that are sent to them, and in particular they also act as a standardization center in which they provide a calibration service for these analytical techniques for the whole of Turkish industry.

One of ANAEM's projects involves attempting to use a cheaper quality of Si (500 Ω less pure and with more traps). They are using irradiation by thermal neutrons to cause transmutation to P to compensate and so reduce the conductivity. The numbers and levels of traps are being investigated by thermally stimulated conductivity (TSC) for which they have constructed their own system; this project is under Dr. S. Özdemir, who is the assistant director of ANAEM.

4 THE MINERAL RESEARCH INSTITUTE (MTA), ANKARA

MTA (Maden Tetkik ve Arama) is situated alongside the campus of METU but is completely independent of it. MTA was set up 50 years ago to aid in the exploitation of the many minerals found in Turkey. There are some 2,000 technical staff in mining, geology, geophysics, geomorphology, chemistry, physics, petroleum sciences, and metallurgy working in 10 technical departments. Fethullah Özelçi coordinator of the geophysics department, gave me a careful introduction to the background of MTA and additional discussions were held with the deputy director Dr. Askin Volkan concerning the mission of MTA, which is to explore the economic natural resources of the country, carry out geological surveys, mineral exploration, and technical analyses and to train

Turkish geologists and engineers. MTA collaborates with the United States Geological Service and with the British Geological Survey amongst other international organizations. It was determined that I should visit the scientific and technical division which includes a ceramics department. The technical sections are directed by Dr. Ahmed Sönmer. I was able to meet one research engineer on mineral processing, Mehmet Yildirim, who is also a graduate student at METU. One of his projects has been to work with alternative supplies of sands for glass manufacturing in Turkey.

The other extensive laboratories of MTA were not visited as my time had been taken up with introductions to the various directors. I was invited to return to visit the extensive MTA facilities and laboratories. Most publications and proceedings at MTA are carried out in Turkish though the senior scientists speak German, French, or English, with many having studied abroad.

5 TÜBITAK

The Scientific and Technical Research Council of Turkey (Tübitak) is the major government organization set up in 1963 to carry out, promote, encourage, and aid in all phases of basic and applied research in education and in the formation of Turkish government national policy on science and technology. Tübitak is organized under a director, aided by three secretaries. I met Dr. Mehmet Tomak, one of the three secretaries in the headquarters of Tübitak, located in Kavaklidere, Ankara.

Tübitak is organized in seven research groups: environment and oceanography; basic sciences; engineering; agriculture and farming; medicine; veterinary sciences; and training and education. Engineering is arranged in five groups: mechanical, electrical, civil, chemical, and mineralogical. There are also five research institutes operated by Tübitak. They are: (1) the Building Research Institute, which is in the process of being transferred to the METU campus; (2) Electronics Research Institute, which is installed on the METU campus alongside the Department of Electrical Engineering; (3) Ballistics Research Institute, which is located in Ankara; (4) Basic Science Research Institute, which is, I believe, alongside the Marmara Research Institute; and (5) Mamara Scientific and Industrial Research Institute in Gebse, situated about 40 kilometers from Istanbul on the coastline of the Sea of Marmara. It is this latter institute that I visited.

The research institute at Gebse is so vast in scale that it was only possible for me to visit a tiny part of the Materials Research Division. I met the director of the Marmara Research Institute, who is also the director of the Electronics Research, Professor Yilnaz Tokad, as well as Dr. Mehmet Tomak, who had come from the Ankara office. The present director of the Marmara Research Institute was previously at METU (I believe I had met him several years earlier at METU).

I visited the Materials science group, meeting with the director, Dr. Şefik Güvleç, who had studied abroad in Germany and was more proficient in German than in English. Work in the Materials Department is on the following subjects: (1) metal forming and mechanical properties, (2) physical properties, electron microscope studies, x-ray diffraction, crystallography, and ceramics; (3) corrosion and surface treatment; (4) alloy development; (5) the technology of casting, both ferrous and nonferrous metals; (6) nondestructive testing (NDT); (7) extraction metallurgy; and (8) welding technology.

Several projects are in progress in the Materials Department, some in-house, others sponsored or in collaboration with Turkish Industry. The in-house projects being carried out are on composite materials, high-strength Maraging steels, and metallic glasses. Work on homogeneous, aluminum 6000 alloys is being carried out for the Karabük Steel Company concerning the effects of extrusion velocities on mechanical properties. The NDT is undertaken using ultrasonic probes, where a range of very large axles and wheels are being examined.

The equipment available includes: (1) vacuum furnaces for casting 1 kilogram quantities, as well as a pilot plant for 50 kilograms; (2) ion plasma system for nitriding steel; (3) scanning electron microscopes and transmission electron microscopes; (4) a well-equipped x-ray diffraction laboratory with pole-figure attachment; (5) differential thermal gravimetry (DTG); (6) particle size analysis; (7) atomic absorption analyzer (two systems); (8) wet chemistry; (9) optical microscopy. The subjects under study are diffusion welding, metal glass quenching, slag refinement. There is a corrosion laboratory where the effects of SO_2 humidity and salt spray are examined on steels and aluminum alloys.

The mechanical testing laboratory has a 500-ton rolling mill to study the extrusion process, and a 100-ton tensile testing machine and a creep tester, (1000°C).

Ceramic studies are carried out under Dr. Özkan, who studied at Leeds, UK. He is concerned with clays, refractories, magnetic ceramic, and piezoelectric PZT materials. Some of these studies are aided by the United Nations Industrial Development Fund.

A clean room (class 10000) is being set up for semiconductor integrated circuit work. Masks for lithography are being designed and made, though the use of emulsions leads to 10-μm features at best. Step-and-repeat lithography is under development. The necessary equipment is not completely available and an early model of a Kaspar optical aligner is being used. Some work has been started on lithium niobate surface acoustic wave (SAW) devices. Fiber optics is under development using a CO_2 laser and polyethylene-coated fiber.

The Marmara Research Institute is very extensive and it is quite impracticable to attempt to visit even in part in 1 day, particularly since much time is paid in courtesy visits to the directors involved. Finally, two other research efforts not related to material sciences should be mentioned. In the microprocessing laboratory of the Mamara Research Institute complete systems are being designed and constructed to be installed on the Bosphorus bridge for toll collection purposes. There is a group working with LANDSAT 5 data to estimate the wheat harvest in Turkey and to monitor water temperatures in the seas around Istanbul and the Bosphorus.

6 CONCLUSIONS

Arrangements for visiting scientific institutes in Turkey can be most usefully organized with the help of Tübitak. Considering recent developments, a knowledge and background of METU is a great advantage to obtain introductions to the various institutes in Turkey. A most useful, helpful, and knowledgeable person is Dr. Mehmet Tomak, who is one of the three secretaries responsible for running Tübitak, as well as a past chairman of the Department of Physics METU and presently a professor in that department.

The following interesting studies in the materials sciences that came to my notice are on: (1) high temperature polymers, by Dr. Levent Topare, in the Department of Chemistry, METU; (2) stress corrosion studies by Professor M. Doruk, Department of Metallurgical Engineering, METU; (3) texture and mechanical properties by Dr. T. Öztürk, Department of Metallurgical Engineering, METU; and (4) Elastic constants and thermal expansion studies of crystalline materials by Dr. H. Özkan, Department of Physics, METU.

Almost all of the personnel I met seemed to hold two appointments--professor at a university and member of a research institute. The personnel were all very friendly and very open about their work. They did voice their problems to be: (1) the difficulty to attract and retain scientific personnel; (2) difficulties to obtain equipment necessary for advanced work; (3) severe difficulties and delays in obtaining small items of everyday use (chemicals, small parts). Nevertheless all were concerned to build up scientific and technological programs to benefit the developing industries in Turkey.

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